RELATIONSHIP OF NORMAL INCIDENCE RADIATION TO MAXIMUM VISIBILITY AT BLUE HILL OBSERVATORY

CHARLES V. CUNNIFF

U. S. Weather Bureau, Blue Hill Observatory, Milton, Mass.

[Manuscript received February 27, 1957; revised April 10, 1957]

Normal incidence radiation, that which is received on a surface at a right angle to the sun, is of interest to agriculturalists, engineers, and others. To provide an estimate of normal incidence radiation when measurements are absent, the relationship of this radiation to horizontal visibility was investigated for those times when there were no clouds in front of the sun. In this paper are presented in graphic form the average values of normal incidence radiation for the principal air masses at various maximum visibilities for each month of the year.

According to [1], air mass "is the length of the atmospheric path traversed by the sun's rays in reaching the earth, measured in terms of the length of this path when the sun is in the zenith." Maximum horizontal visibility, as observed at the Blue Hill Observatory, describes the greatest degree of transparency of the atmosphere in any direction. It is defined as the maximum distance, in miles, at which an object can be seen and the clearness with which its details can be discerned [2]. Visibility values are observed and recorded by the Blue Hill Observatory staff. Normal incidence radiation readings are taken at the Observatory by the U. S. Weather Bureau with an Eppley tube, and recorded on a Brown Electronik recorder.

Data for the years 1949 to 1956 were used in this investigation. Table 1 lists the number of observations taken for the four principal air masses for each month. The maximum number of observations occurred during August, September, and October, while the minimum occurred during the spring months of April and May. There was an average of 16 observations per month for the 8 years of record for the No. 3 air mass in September, while an average of only 9 per month for the No. 4 air mass in April. No attempt was made to draw a curve for the No. 2 air mass in November, due to the sparseness of observations (35). During December and January there were no observations taken at the No. 2 air mass because of the low solar trajectory. The observations for each of the four air masses were further subdivided according to maximum horizontal visibility and mean values of radiation for each 10-mile multiple of visibility were obtained by dividing the total value of all observations at each multiple by the number of observations. Figure 1 shows plots of these values with curves fitted to them by eye.

These curves indicate a three-dimensional characteristic: (1) Increased values of radiation with decreased air mass. (2) Increased values of radiation with increased visibility. (3) Increased values of radiation from summer to winter.

1. Low air mass numbers indicate a decrease in the length of path of the radiation, and thus a reduction in the amount of radiation reflected, scattered, or absorbed by the atmosphere and atmospheric contaminants. The average radiation difference between each successive air mass, maintaining the same visibility, is about 0.13 langley per minute.

2. Visibility is a criterion of the degree of contamination (dust, haze, smoke, etc.) in the atmosphere. Maximum visibility rather than average visibility was used, as it more closely represents true air mass visibility. Pockets of local contamination (especially over the city 10 miles north) greatly affect the average visibility but have little or no effect on the maximum visibility in some other direction. There is an average difference of 0.2 to 0.3 langley per minute in the mean beam radiation intensity corresponding to the maximum visibility of 10 miles and that corresponding to 100 miles visibility.

3. A combination of several conditions accounts for the seasonal differences. For example, at perihelion (December) the intensity, due to the nearness of the earth to the sun, is roughly 7 percent greater than at aphelion (June) [3]. The amount of water vapor in the air is considerably less in winter than in summer, and therefore less radiation is absorbed, resulting in higher intensities in winter. Various months were paired to indicate the maximum variability between seasons. As indicated above, December and June along with January and July produced the greatest disparity. These differences were on the order of 0.1 to 0.3 langley per minute for comparable air masses and visibilities.

TABLE 1.—*Number of observations for each air mass for each month*

Air mass	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2		87	94	97	86	98	101	103	124	124	35	
3	89	92	104	80	80	100	98	112	130	129	89	108
4	91	98	105	70	71	88	91	110	120	127	93	104
5	93	99	96	66	66	78	85	104	111	120	87	102

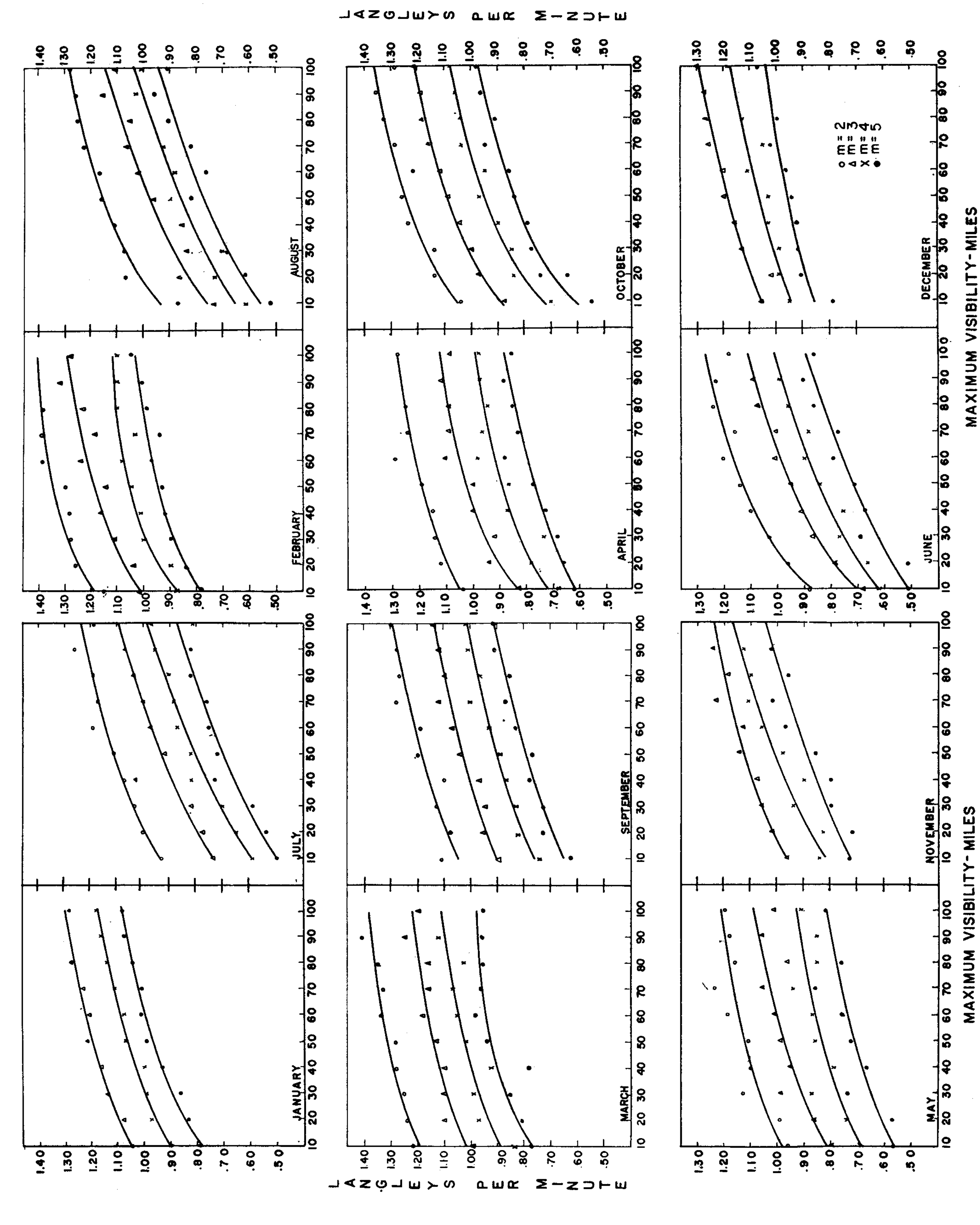

FIGURE 1.—Plots of mean values of solar radiation for each 10-mile multiple of visibility and subdivided according to air mass. Months are paired to show maximum variability between seasons.

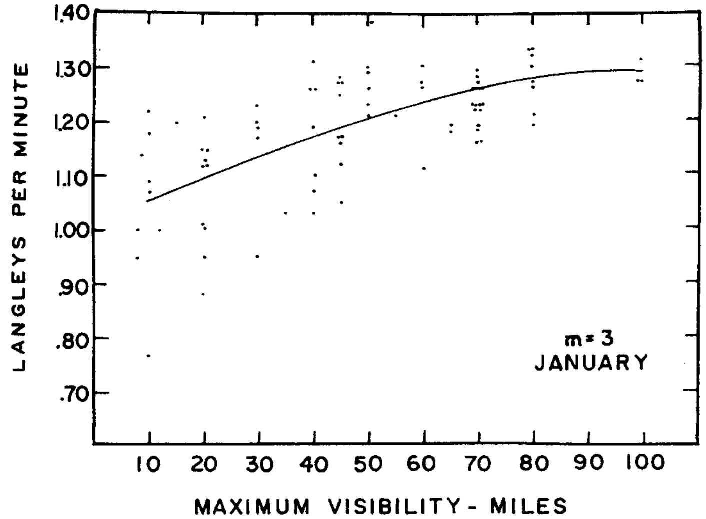

FIGURE 2.—Plot of all observations of normal incidence radiation, January 1949–56, at air mass 3.

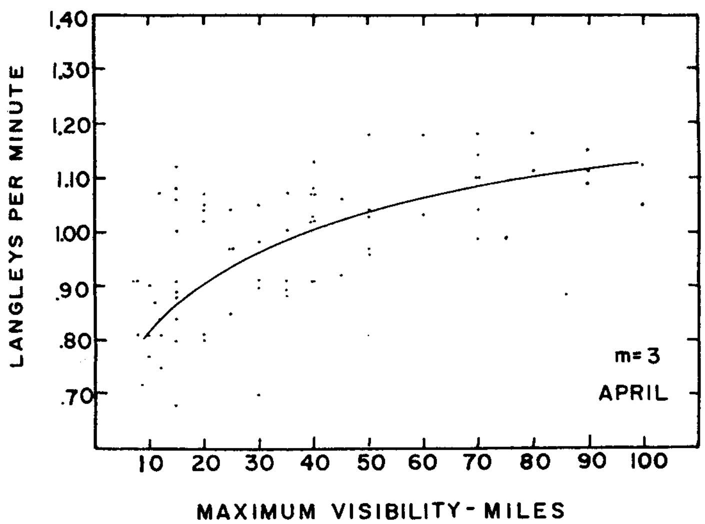

FIGURE 3.—Plot of all observations of normal incidence radiation, April 1949–56, at air mass 3.

Figures 2 to 5 are plots of actual values of all observations for four selected months, with curves fitted by eye to the average values of the plots. These plots show the amount of variability in individual observations to be greater at lower visibilities than at high. This probably means that the observations taken with high visibilities are characterized by a narrower range of water vapor content than those taken with the lower visibilities. That is, when the visibility is very good the air is always dry, but with low visibilities (near 10 miles) the air may be dry or moist. Thus, at high visibilities the seasonal variation due to varying water content is less marked than at low visibilities, for the observations made at high visibilities will have more nearly the same water content that those at low visibilities regardless of season. These plots are a good indication of the amount of variability encountered throughout the entire study.

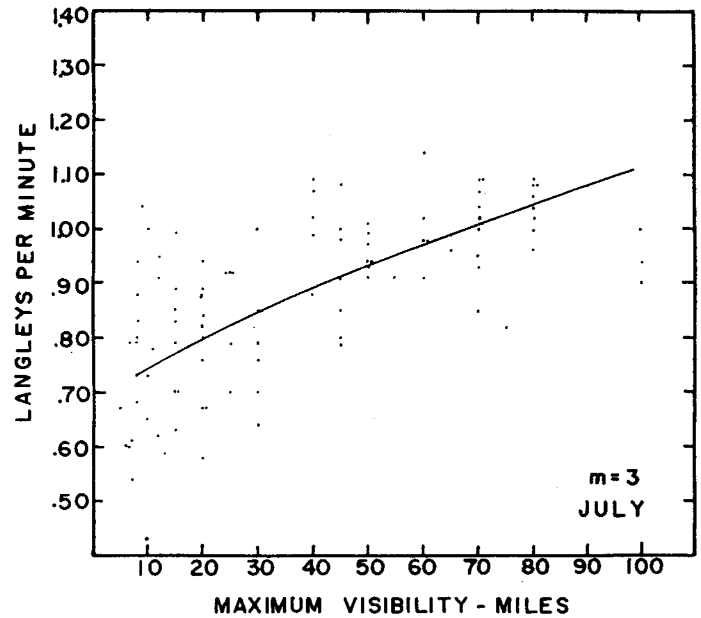

FIGURE 4.—Plot of all observations of normal incidence radiation, July 1949–56, at air mass 3.

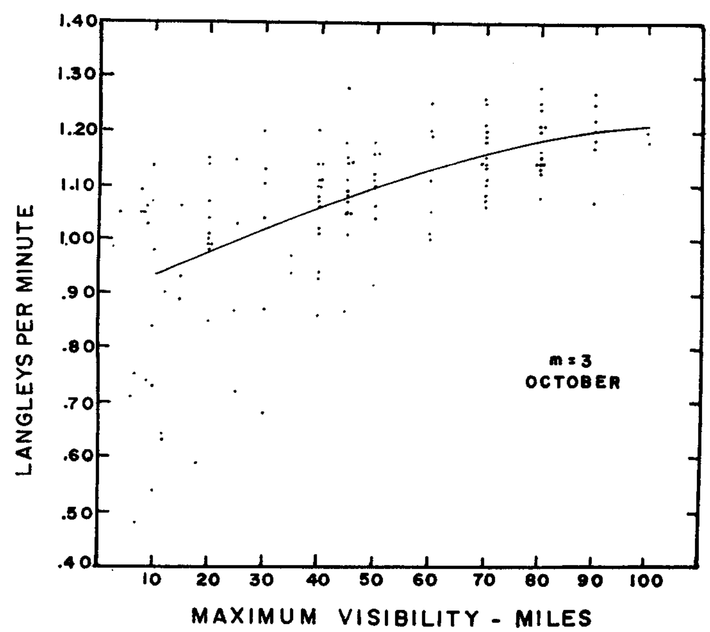

FIGURE 5.—Plot of all observations of normal incidence radiation, October 1949–56, at air mass 3.

REFERENCES

1. *Smithsonian Miscellaneous Collections*, vol. 114, "Smithsonian Meteorological Tables," 6th Rev. Ed. 1951, p. 422.
2. *Meteorological Glossary*, Chemical Publishing Co., 1951, p. 204.
3. W. J. Humphreys, *Physics of the Air*, 3d Ed., McGraw-Hill Book Co., Inc., New York, 1940, p. 86.